Bird Population Changes After Timber Harvesting of a Mixed Conifer Forest in Arizona

Kathleen E. Franzreb

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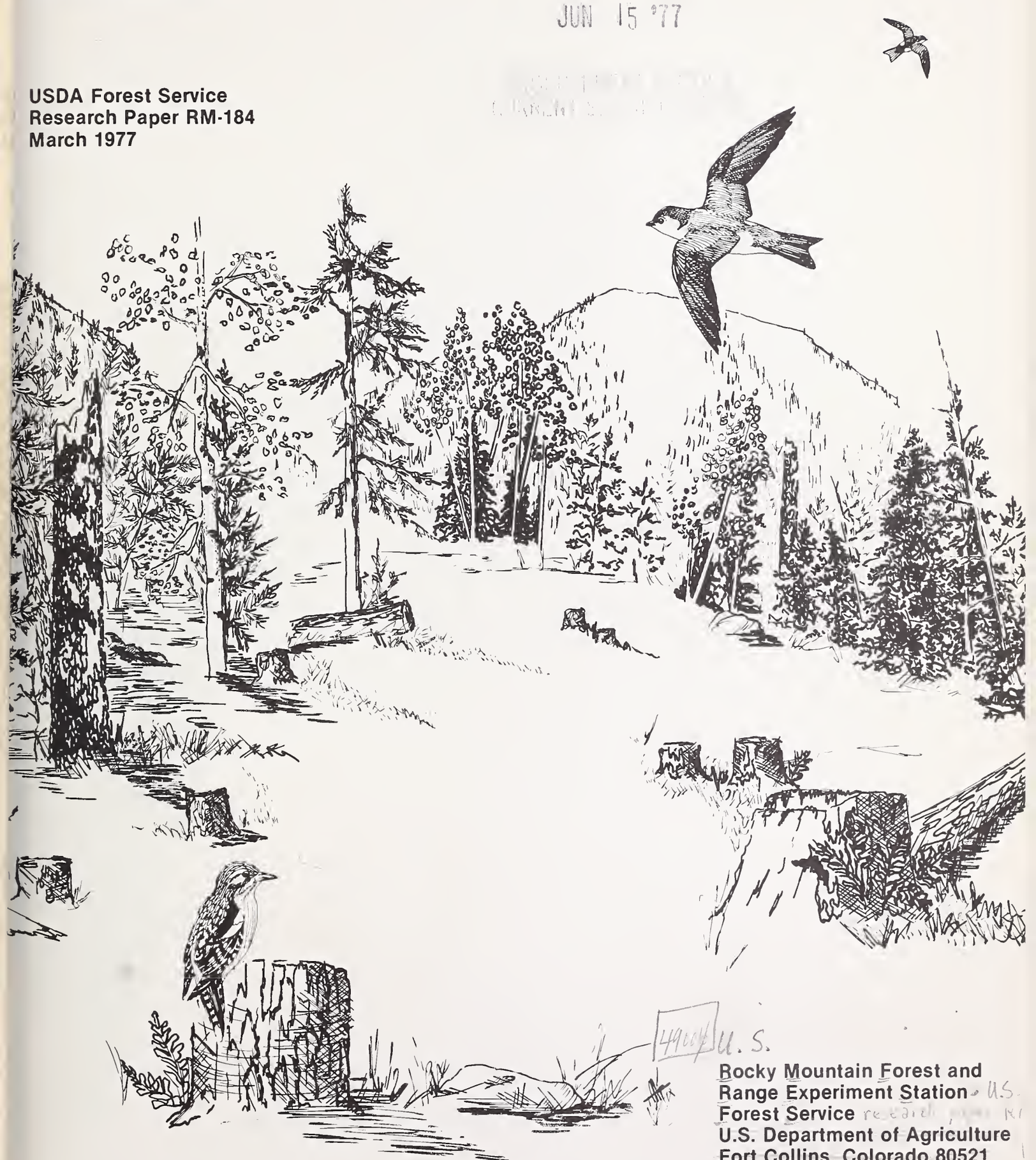

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Abstract

Selective overstory removal in a mixed conifer forest in the White Mountains of Arizona significantly reduced total bird density. However, a number of species attained higher densities in the logged area than in the control area. In both habitats, avian usage of Douglas-fir, white fir, and Engelmann spruce far exceeded that expected on the basis of foliage volume. Birds were more frequently observed on snags and in quaking aspen in the logged area than in the control site. Gray-headed juncos and house wrens heavily utilized logging slash. Tall trees were preferred in both habitats. The behavior of the yellow-bellied sapsucker, mountain chickadee, ruby-crowned kinglet, yellow-rumped warbler, and gray-headed junco was examined with regard to tree species selection and tree height preferences. Timber harvesting affected the behavior of some species, but for others there was little change.

Keywords: Timber harvesting, mixed conifer forest, bird population changes.

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Management Highlights

Timber harvesting (selective overstory removal) in the White Mountains of Arizona was detrimental to some bird species, but was beneficial to others. The number of avian species in the harvested and control areas (figs. 1, 2) was similar. In 1973 there were 30 species in the harvested area and 29 in the control area, whereas in 1974 there were 35 species in each study site.

Species composition and densities varied considerably between the two study areas. Several species such as the Coues' flycatcher[3], purple martin, and western bluebird, were restricted to the harvested site. This area was also more suitable for the red-tailed hawk, American kestrel, yellow-bellied sapsucker, olive-sided flycatcher, violet-green swallow, house wren, and gray-headed junco. Conversely, the unharvested area was preferred by the western flycatcher, brown creeper, golden-crowned kinglet, ruby-crowned kinglet, yellow-rumped warbler, red-faced warbler, and hermit thrush.

Total densities were considerably higher in the unharvested habitat each summer. Population size may be determined by a number of factors, including foliage volume, nest site availability, degree of predation, microclimate, and food abundance.

Some birds showed strong preferences for certain tree species, while other trees were less frequently used. In both the harvested and unaltered habitats, birds most frequently visited Douglas-fir, white fir, and Engelmann spruce, which were utilized in excess of the proportion of volume each comprised in the environment. Usage of quaking aspen and snags was higher in the logged area. Ponderosa pine and southwestern white pine were frequented less than would be predicted on the basis of foliage volume. By leaving more trees of the most desirable species, a harvested habitat may be capable of supporting more birds of some species than it would otherwise.

Tall trees were preferred in both habitats, undoubtedly because they provided more foliage

[3]*Scientific names of plants and animals mentioned are listed in the Appendices.*

Figure 1.—The unlogged study area.

Figure 2.—The harvested study area sustained a moderately heavy overstory removal. Logging created a considerable amount of slash.

volume. The yellow-rumped warbler and ruby-crowned kinglet predominantly selected tall and very tall trees. Thus, some tall trees should be left.

Slash piles were very important, especially for gray-headed juncos and, to a lesser extent, for house wrens. To prevent a reduction of these species, at least some slash piles should be allowed to remain after a harvest.

Snags were a vital habitat component for many species, particularly those that nest in cavities (violet-green swallows, mountain chickadees, house wrens). Birds use snags for foraging, observing, preening, singing, and nesting. The majority of nests observed in the logged area were in snags. Many nests, especially those in the middle or top of spruce and fir, were not found. Apparently, the relative abundance of snags as well as ease of finding food attracted such aerial foragers as the violet-green swallow to the logged area. There was evidence of severe competition for suitable nest cavities in snags; numbers of such cavities may play a vital role in population regulation of some species.

Introduction

The occurrence of avian species within a given habitat depends on the environment which fulfills each species' niche requirements. Habitat changes can result in a reduction in the number of species and may affect densities of the original species occupying the area. However, the altered habitat subsequently may be suitable for certain species which were not present prior to modification. In addition, the habitat may be enhanced for some species which originally occurred in low numbers.

Logging may appreciably affect the bird population of a forest. Clearcutting 4 to 8 ha[4] blocks of Douglas-fir in northwestern California caused a marked change in avian species composition. Total bird density declined initially, but within a year it had recovered (Hagar 1960).

Timber harvesting reduces tree densities, foliage volume availability, and amount of canopy. Open habitat is more prevalent and less foliage is available for foraging and nesting. Windthrown timber and slash piles remaining from the logging operation, however, may provide additional foraging sites for certain species.

Avian densities and composition have been examined in burned (Blackford 1955, Bock and Lynch 1970), flooded (Yeager 1955), and stripmined (Karr 1968) habitats. The effects of vegetation removal were studied by Kilgore (1971). In these studies, species densities and composition were significantly affected by habitat alterations.

After a marked alteration of the habitat such as timber harvesting, species utilizing the area may change their tree species preferences. In addition, birds may forage in shorter trees than otherwise would be selected. Degree of usage of trees may depend on the amount of foliage volume each tree species represents in the habitat. In examining an oak-juniper woodland and ponderosa pine forest in Arizona, Balda (1969) found that the foliage of some tree species was used at random, whereas foliage of others at given heights was either heavily selected or avoided. Certain tree species were preferred; others were used in the proportion they were available in the habitat, while some were seldom used.

The purpose of this investigation was to determine changes in avian species composition and densities in a mixed conifer forest after timber harvesting. Tree species preferences and tree height selection were examined to determine changes in habitat utilization.

Description of Study Area

The Willow Creek study area (201.6 ha logged; 131.2 ha unlogged) is located approximately 80 km[4] south of Springerville on the Coronado Trail in the Apache-Sitgreaves National Forest, Greenlee County, White Mountains, Arizona. It is a USDA Forest Service experimental watershed ranging in elevation from 2,682 to 2,805 m. Latitude is approximately 33°6' and longitude is 109°3'.

[4] *Data in this paper are presented in SI (metric) units. Some convenient conversions are:*

SI	*U.S. equiv.*
1 kilometer (km)	*0.62 mile*
1 meter (m)	*39.37 inches*
1 centimeter (cm)	*.39 inch*
1 hectare (ha)	*2.47 acres*
1 square centimeter	*.155 square inch*

Climate

Annual precipitation in the Willow Creek watershed averaged 76.26 cm during the last 15 yrs. The winter of 1973 was extremely wet, with 40.39 cm of precipitation falling between January 1 and May 31. The long-term mean for this period was 17.08 cm, which was most closely approximated during the course of this study by the winter of 1974 (21.07 cm). Precipitation totaled 108.1 cm and 54.2 cm in 1973 and 1974, respectively (mean 76.2 cm).

Temperature data for Castle Creek (2,592 m elevation), 8 km from Willow Creek, indicated a mean daily minimum of −4.7 °C, a mean daily maximum of 15.6 °C, and a daily mean of 5.7 °C. Freezing nighttime temperatures occurred several times in May and June during both summers. During the avian breeding season (May to August), the mean daily maximum temperature was 23.1 °C, with a minimum of 2.8 °C and a daily mean of 13.1 °C.

Vegetation

Vegetation type is mixed conifer forest. Scientific names for trees are given in appendix I. A list of shrubs and grasses, grass-like plants and forbs forming the understory is given in appendix II. Ponderosa pine and Douglas-fir are dominant tree species. In the harvested area quaking aspen is also an important species.

Methods

Vegetation Analysis

Mature trees and saplings in the logged and unlogged areas were sampled by the plotless-point quarter method (Cottam and Curtis 1956). One hundred stations (400 mature trees) were sampled within a 15.5 ha plot in each area. Saplings (d.b.h. less than 7.6 cm or 3 in and more than 1 m in height) were considered separately (using 30 stations in each area). For the tree in each quadrant closest to the center stake, the following data were taken: species, height, d.b.h. (diameter measured at ground level for saplings), length of longest branch, distance from the trunk along the branch to the point where live foliage began, height from the ground to the first branch, and distance from the tree to the center stake. These variables were used in the calculation of live foliage volume for each tree species. Using these measurements and the following formulas, absolute and relative values were obtained for density, dominance, and frequency:

Total density of all species =

$$\frac{\text{unit area}}{(\text{mean point-to-point distance})^2}$$

Relative density =

$$\frac{\text{number of individuals of a species}}{\text{total individuals of all species}} \times 100$$

Density =

$$\frac{\text{relative density of a species} \times \text{total density of all species}}{100}$$

Dominance =

(density of a species)
× (average dominance value for a species)

Average dominance was defined as basal area of all trees sampled for a species divided by the number of trees sampled. Basal area was obtained by taking $\pi(\text{d.b.h.}/2)^2$.

Relative dominance =

$$\frac{\text{dominance for a species}}{\text{total dominance for all species}} \times 100$$

Frequency =

$$\frac{\text{number of points at which species occurs}}{\text{total number of points sampled}}$$

Relative frequency =

$$\frac{\text{frequency value for a species}}{\text{total frequency values for all species}} \times 100$$

Importance Value = relative density + relative dominance + relative frequency

Avian Species Composition and Densities

Censusing was begun in June 1973 and continued throughout the summers of 1973 and 1974. All avian species names follow the A.O.U. checklist (1957, 1973) and are given in appendix III.

The spot-map method (Williams 1936) was used to census birds. A 15.5-ha grid pattern was established in both the harvested and unaltered areas using plastic flagging placed at 25-m intervals along 9 parallel lines, each 390 m in length. Parallel lines were 50 m apart. Every flag was labeled with a number corresponding to the transect line and a letter corresponding to the distance traveled from the beginning of the line.

Location of each individual bird was plotted on a grid map. Points on the map were coded to signify singing male, nonsinging male, female, fledgling, or nest. Territories were then delimited for each singing male. Number of territories multiplied by two gave number of breeding birds in 15.5 ha which was converted to number per 40 ha, a commonly used base in avian studies. The study plot was censused six times each month, beginning one-half hour after sunrise when avian activity was highest and continuing for up to 3 hrs.

For most birds, territorial defense declined or was nonexistent in August, making the spot-map method unreliable. Therefore, a mean of the June and July values was used to determine density from the spot-map data. Species diversity values (H') (Shannon 1948) were calculated for results obtained in each study area.

Avian Preferences for Tree Species and Tree Heights

When a bird was observed in a tree, the following information was recorded: bird species, sex (if possible), tree species, and tree height. Data were collected throughout the summers of 1973 and 1974 at all times of day by systematically traversing the area within the grid pattern.

Data for tree species and tree height preferences were depicted separately for five avian species: yellow-bellied sapsucker, mountain chickadee, ruby-crowned kinglet, yellow-rumped warbler, and gray-headed junco. These species were selected because they are representative of cavity, open-cup, and ground-nesting species, and because they occurred in sufficient densities in both study areas to provide adequate sample sizes.

Preferences for certain tree species were noted by comparing frequency of use of a particular tree with its percent availability in the habitat as determined from the foliage volume data.

Preferences for trees of certain heights were also ascertained by comparing usage date to frequency of availability of each tree height class. The first height class contained trees up to 3.0 m tall. Each successive height class included all trees an additional 3.0 m in height, regardless of species. To facilitate comparison of tree height selection, heights were divided into four categories: short, trees up to and including 9 m; medium, between 9 m and 24 m; moderately tall, between 24 m and 30 m; and tall, over 30 m.

Results

Vegetation

Trees on the Willow Creek study area were harvested by the overstory removal system. The extent of the treatment is indicated in table 1. Basal area was reduced to only 18.6 percent of the original amount. This figure is close to the 16.2 percent obtained for the entire logged watershed by Gottfried and Jones (1975).

Plotless-point quarter analysis for mature trees indicated that, in the control area, total tree density was 626.2 versus 167.7 trees per ha in the logged study site. In the control area, Douglas-fir had the highest density as well as the highest importance value (table 2). Ponderosa pine was next in importance. In the logged area, Douglas-fir also showed the highest density and importance value. However, snags and quaking aspen, neither of which were removed during logging, were next in importance. The category "snags" contained representatives of every tree species and was considered as one vegetation type.

In addition to analysis of trees with d.b.h. greater than 7.6 cm, saplings were also sampled by the same technique (table 3). Aspen was just beginning to sucker in the logged area during the summer in which the vegetation data were collected, but the sprouts were not of sufficient height to be counted. Sprouts were tall enough to have been counted in 1974, but they did not appear to be of any importance to the birds present. Total sapling density was 516.5 per ha in the unlogged area and 354.9 per ha in the logged area.

Timber harvesting debris, consisting of limbs and assorted cull trees, formed an additional

Table 1.—Tree species density, average diameter at breast height (d.b.h. ≥ 7.6 cm), and basal area.

Tree species	Tree density		Average d.b.h.		Basal area	
	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged
	No./ha		*Cm*		*M²/ha*	
Ponderosa pine	4.6	112.7	44.4	35.7	0.81	16.32
Southwestern white pine	8.8	109.6	17.3	20.9	.24	4.98
Subalpine fir	13.0	3.1	16.6	23.0	.35	.15
Douglas-fir	42.3	194.1	16.0	26.4	2.29	17.04
White fir	19.7	51.7	14.9	24.8	.52	4.87
Blue spruce	9.6	12.5	13.4	15.8	.16	.33
Engelmann spruce	19.3	31.3	18.1	21.6	.61	1.20
Quaking aspen	29.3	50.1	24.0	19.9	1.96	1.96
Snag	21.0	61.1	32.6	22.4	2.52	4.02
Total	167.7	626.2			9.47	50.88

Table 2.—Composition of trees (d.b.h. ≥ 7.6 cm) on a mixed conifer forest, White Mountains, Arizona

Species	Density		Relative density		Relative dominance		Relative frequency		Importance value	
	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged
	No./ha									
Ponderosa pine	4.6	112.7	2.8	18.0	9.6	30.5	4.0	19.3	16.3	67.8
Southwestern white pine	8.8	109.6	5.3	17.5	3.1	10.6	6.1	18.6	14.5	46.7
Subalpine fir	13.0	3.1	7.8	.5	4.4	.3	8.7	.7	20.8	1.5
Douglas-fir	42.3	194.1	25.3	31.0	16.1	35.2	22.7	26.1	64.0	92.3
White fir	19.7	51.7	11.8	8.3	6.5	7.6	12.3	8.6	30.5	24.5
Blue spruce	9.6	12.5	5.8	2.0	2.0	.7	6.1	2.5	13.9	5.2
Engelmann spruce	19.3	31.3	11.5	5.0	7.6	2.7	11.9	5.4	31.0	13.0
Quaking aspen	29.3	50.1	17.5	8.0	18.5	4.1	15.2	8.2	51.2	20.3
Snag	21.0	61.1	12.5	9.8	32.2	8.3	13.0	10.7	57.8	28.7
Total	167.7	626.2	100.0	100.0	100.0	100.0	100.0	100.0	300.0	300.0

Table 3.—Composition of saplings (d.b.h. < 7.6 cm) on a mixed conifer forest, White Mountains, Arizona

Species	Density		Relative density		Relative dominance		Relative frequency		Importance value	
	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged	Logged	Unlogged
	No./ha									
Ponderosa pine	0	56.0	0	10.8	0	10.0	0	15.9	0	36.7
Southwestern white pine	5.9	51.7	1.7	10.0	.2	9.1	3.2	11.1	5.0	30.3
Subalpine fir	0.0	8.6	0	1.7	0	1.5	0	3.2	0	6.4
Douglas-fir	171.5	292.7	48.3	56.7	71.1	63.7	41.3	46.0	160.7	166.4
White fir	141.9	77.5	40.0	15.0	21.7	10.1	38.1	17.5	99.8	42.5
Blue spruce	14.7	25.8	4.2	5.0	2.0	4.9	6.4	4.8	12.5	14.7
Engelmann spruce	20.7	0	5.8	0	5.1	0	11.1	0	22.1	0
Quaking aspen	0	0	0	0		0	0	0	0	0
Snag	0	4.3	0	.8	0	.7	0	1.6	0	3.1
Total	354.9	516.5	100.0	100.0	100.0	100.0	100.0	100.0	300.0	300.0

understory substratum in the logged area. This debris was partly collected into piles by the Forest Service and served as centers of activity for gray-headed juncos and, to a lesser extent, for house wrens (fig. 3). On July 30, 1973, slash piles were burned to reduce potential fuel for forest fires.

Figure 3.—In 1973 the Forest Service reduced the amount of slash by burning.

Avian Species Composition and Densities

Avian species composition and densities, determined separately for each summer for the logged and unlogged areas, are listed in table 4. Although most species were present during both summers, several species such as the green-tailed towhee, chipping sparrow, olive warbler (unlogged area only), and Grace's warbler (unlogged area only) were observed only one of the summers.

Other species were restricted to one of the study areas. For the logged area such species included the purple martin, western bluebird, and mountain bluebird. In the unlogged area, restricted species included the Townsend's solitaire and Grace's warbler. All of these species were present in low densities. In addition, the brown creeper was primarily restricted to the unlogged habitat. It was not observed in the logged area during 1973, and was seen there on only three occasions in 1974.

Overall avian numbers were higher in the unlogged than the logged area. More birds were present in both study plots in 1974 than in 1973. The majority of species changed in density from one summer to the next. The yellow-rumped warbler was the most common species in both areas.

Data were analyzed by the chi-square test to determine if differences in densities of bird species between logged and unlogged areas were statistically significant. Avian densities were divided into three categories on the basis of species nesting characteristics (ground, open-cup, or cavity). Data for each summer were compared separately. A highly significant difference ($P < 0.01$) in numbers between the control and logged areas was found for each category during each summer.

Species most affected by logging were:

Beneficially Affected	Adversely Affected
American kestrel	Western flycatcher
Great horned owl	Mountain chickadee
Yellow-bellied sapsucker	White-breasted nuthatch
Olive-sided flycatcher	Red-breasted nuthatch
Violet-green swallow	Pygmy nuthatch
House wren	Brown creeper
American robin	Hermit thrush
Western bluebird	Townsend's solitaire
Warbling vireo	Golden-crowned kinglet
Gray-headed junco	Ruby-crowned kinglet
	Yellow-rumped warbler
	Red-faced warbler

These species showed a consistent difference in density of 25 percent or more between the logged and unlogged areas during the breeding season.

Tree Species Preferences

To determine tree species preferences, percent observations for all bird species were considered. The relative density of snags was used in lieu of live foliage volume available.

In the unlogged area (fig. 4), birds strongly preferred Douglas-fir, white fir, and Engelmann spruce. Moderate preferences were demonstrated for subalpine fir and blue spruce. Tree species not used to the extent they were available included ponderosa pine, southwestern white pine, and snags. Only quaking aspen was utilized in approximately the proportion in which it was available.

Table 4.—Breeding densities of birds in Willow Creek

Species[1]	1973		1974	
	Logged	Unlogged	Logged	Unlogged
	No./40 ha			
Turkey vulture		P[2]	P	P
Goshawk				P
Red-tailed hawk	P		5.1	
American kestrel			10.2	P
Band-tailed pigeon			P	P
Mourning dove			P	
Flammulated owl		10.6		10.2
Great horned owl	5.3	5.3	10.2	5.1
Pygmy owl	5.3			
Saw-whet owl	5.3		5.1	
Broad-tailed hummingbird	5.3	5.3	20.5	30.8
Common flicker	13.2	10.6	20.5	25.6
Yellow-bellied sapsucker	15.8	10.6	20.5	10.2
Williamson's sapsucker	2.7	2.7	5.1	5.1
Hairy woodpecker	10.5	11.8	10.2	10.2
Downy woodpecker	7.9	5.3	7.7	10.2
Northern three-toed woodpecker	1.4	2.7	15.4	15.4
Dusky flycatcher	5.3	2.6		
Western flycatcher	2.6	47.6	15.4	48.7
Coues' flycatcher	2.7			
Olive-sided flycatcher			12.8	5.1
Violet-green swallow	15.8	2.6	51.3	10.2
Purple martin	1.4		2.6	
Steller's jay	13.2	15.8	28.2	25.6
Common raven	2.6		P	5.1
Clark's nutcracker	P	P	5.1	5.1
Mountain chickadee	11.8	44.7	30.8	58.9
White-breasted nuthatch		2.6		15.4
Red-breasted nuthatch		2.6	10.2	25.6
Pygmy nuthatch		2.6	10.2	25.6
Brown creeper		39.5	P	51.3
House wren	79.0	26.3	79.5	7.7
American robin	5.3		12.8	5.1
Hermit thrush	36.8	71.0	43.6	76.9
Western bluebird	2.7		5.1	
Mountain bluebird			5.1	
Townsend's solitaire				5.1
Golden-crowned kinglet	5.3	26.3	5.1	30.8
Ruby-crowned kinglet	42.1	71.0	23.1	74.4
Warbling vireo	47.4	21.0	35.9	25.6
Orange-crowned warbler		2.6		
Virginia's warbler			5.1	
Olive warbler				P
Yellow-rumped warbler	100.0	131.6	76.9	89.8
Grace's warbler				25.6
Red-faced warbler	2.6	10.6		25.6
Western tanager	15.8	7.7	15.4	12.8
Black-headed grosbeak				5.1
Pine siskin	2.6	7.9	23.1	25.6
Red crossbill			45.6	
Green-tailed towhee			5.1	
Gray-headed junco	76.3	31.6	74.4	51.3
Chipping sparrow			5.1	5.1
Total	544.0	632.9	758.0	865.9
Diversity	2.69	2.76	3.15	3.19

[1] *Transients: Rufous hummingbird, yellow warbler, Cassin's finch, savannah sparrow, dark-eyed junco, white-crowned sparrow.*

[2] *P = Present*

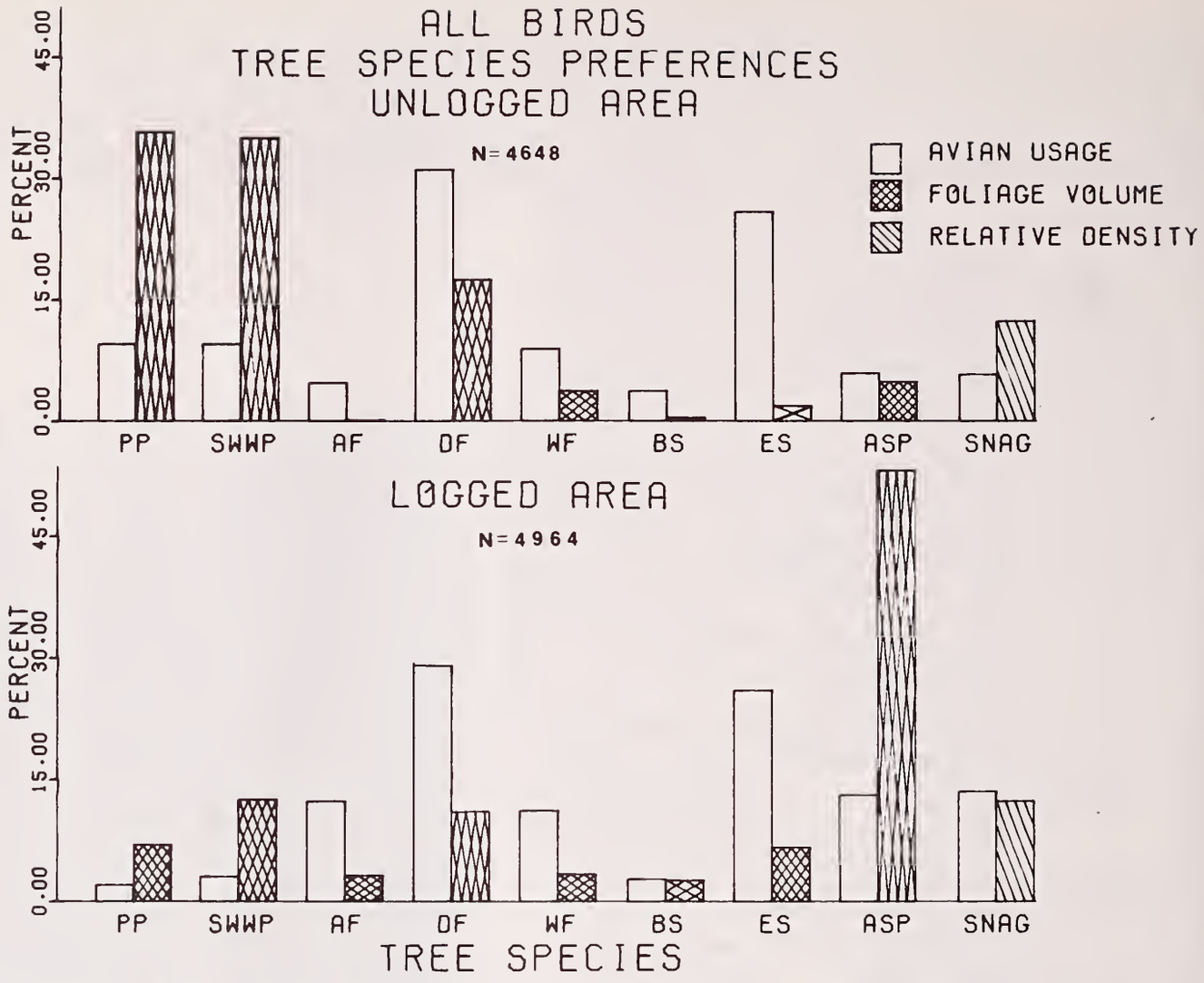


Figure 4.—Tree species preferences of all birds in the unlogged and logged areas. Tree species were abbreviated as follows: PP-ponderosa pine; SWWP-southwestern white pine; AF-subalpine fir; DF-Douglas-fir; WF-white fir; BS-blue spruce; ES-Engelmann spruce; and ASP-quaking aspen. In the unlogged area, foliage volume was 0.2% for subalpine fir and 0.5% for blue spruce.

In the logged area, birds strongly preferred Douglas-fir and Engelmann spruce. Ponderosa pine, southwestern white pine, and aspen were seldom utilized. Snags and blue spruce were used in approximately the same proportion in which they occurred.

Yellow-bellied sapsuckers preferred Engelmann spruce, aspen, and snags in the unlogged area (fig. 5), but showed preferences for subalpine fir, Douglas-fir, white fir, and snags in the logged area. Aspen was chosen far less than the percent it was available, as was southwestern white pine.

The mountain chickadee preferred Douglas-fir, white fir, blue spruce, and Engelmann spruce in the unlogged area (fig. 6). In the logged area, subalpine fir was preferred most, followed by Engelmann spruce and Douglas-fir.

The ruby-crowned kinglet (fig. 7) preferred subalpine fir, Douglas-fir, white fir, blue spruce, and particularly Engelmann spruce in the unlogged area. In the logged area, this kinglet preferred Douglas-fir, white fir, and especially Engelmann spruce.

The yellow-rumped warbler preferred Douglas-fir, white fir, blue spruce, and Engelmann spruce in the unlogged area (fig. 8), and utilized ponderosa pine and southwestern white pine more extensively than did the other four birds. Aspen was selected in about the same percent it was present, whereas snags were rarely chosen. In the logged area, the yellow-rumped warbler utilized subalpine fir, Douglas-fir, white fir, blue spruce, and Engelmann spruce heavily. Aspen was also frequently used but far less than expected on the basis of foliage volume availability.

In the unlogged area, the gray-headed junco (fig. 9) preferred Douglas-fir, white fir, blue spruce, and especially Engelmann spruce. In the logged area it selected subalpine fir, Douglas fir, white fir, blue spruce, and Engelmann spruce. The other tree species were seldom used.

YELLOW-BELLIED SAPSUCKER

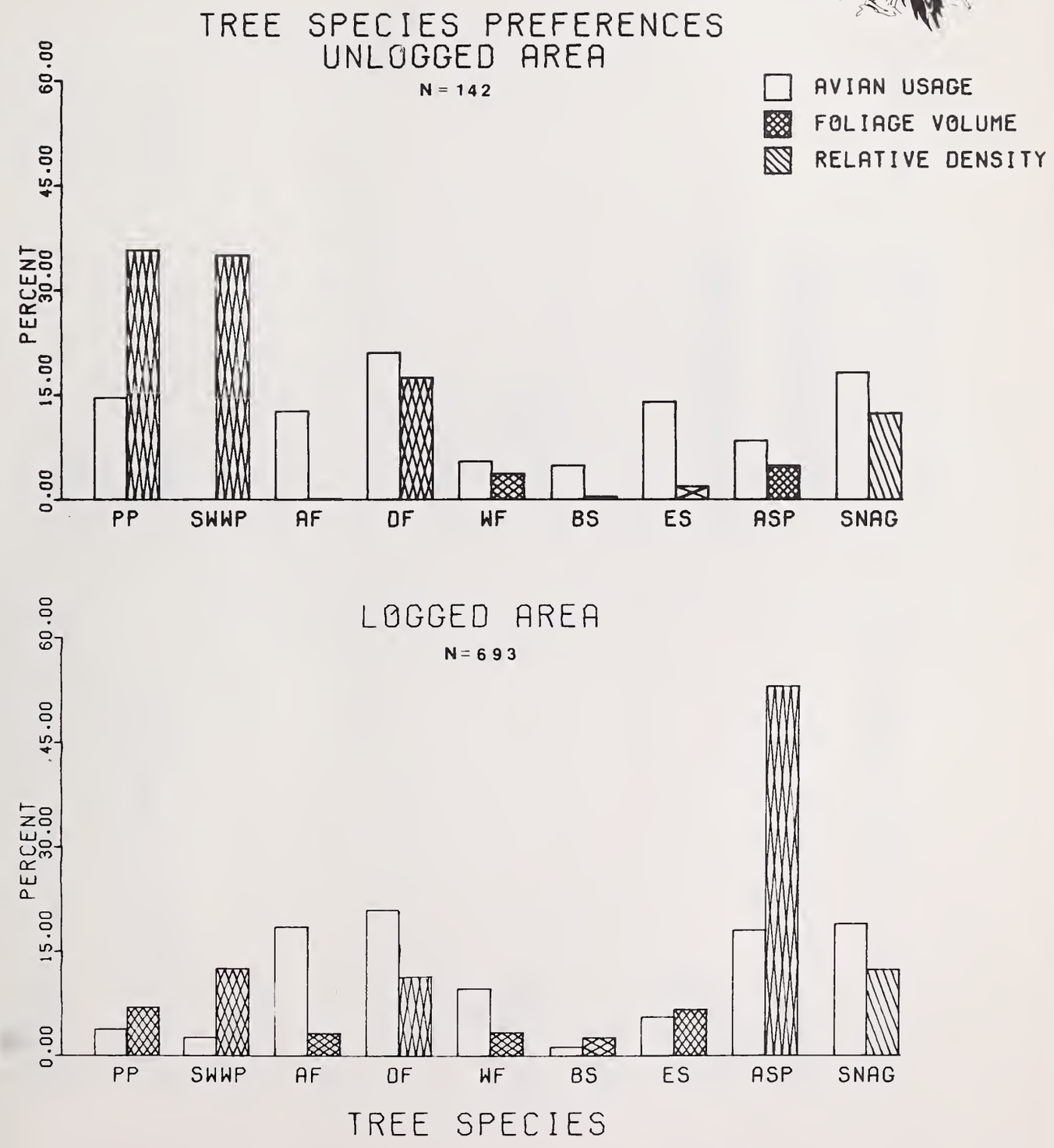


Figure 5.—Tree species preferences of the yellow-bellied sapsucker.

MOUNTAIN CHICKADEE

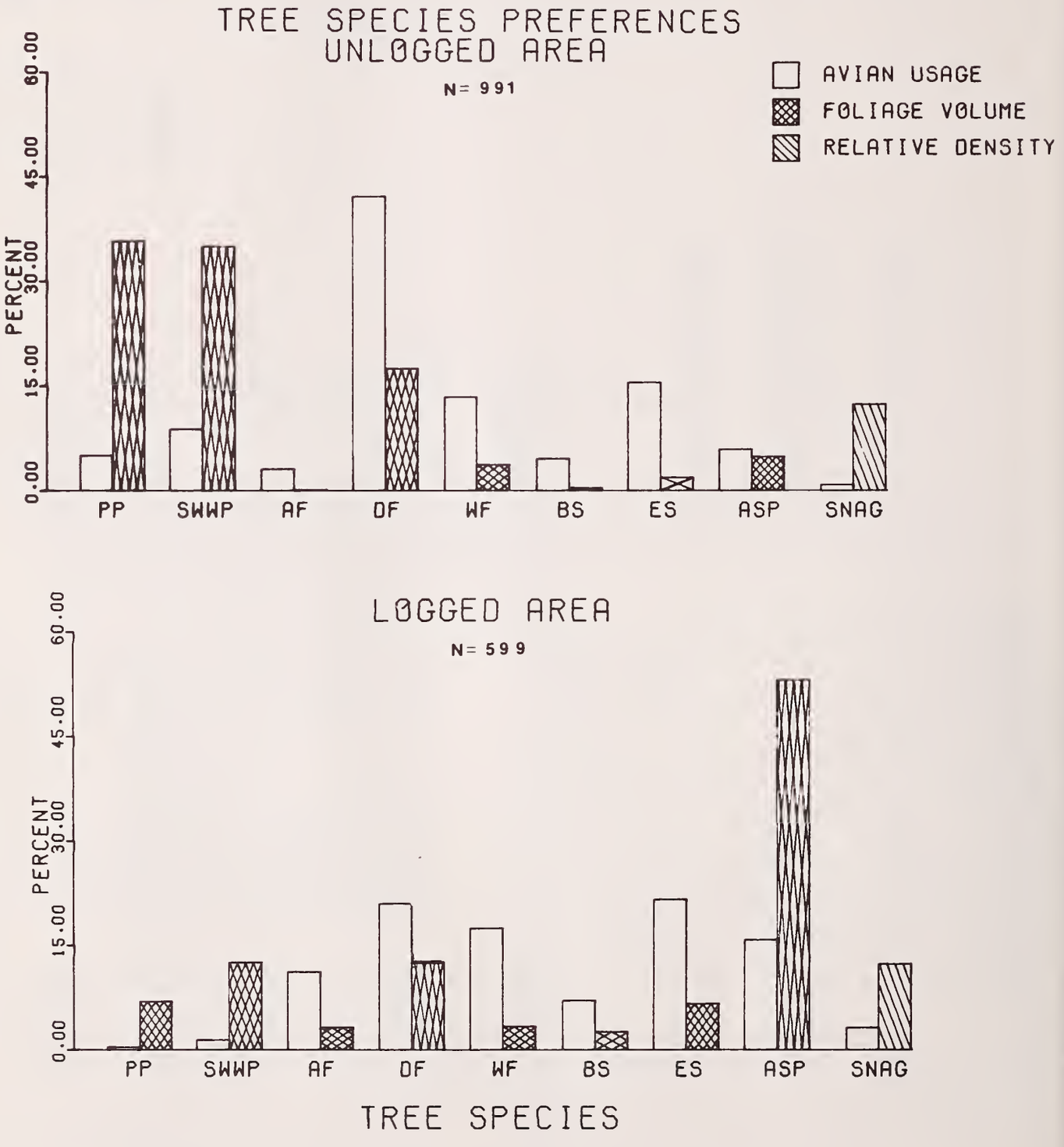


Figure 6.—Tree species preferences of the mountain chickadee.

RUBY-CROWNED KINGLET

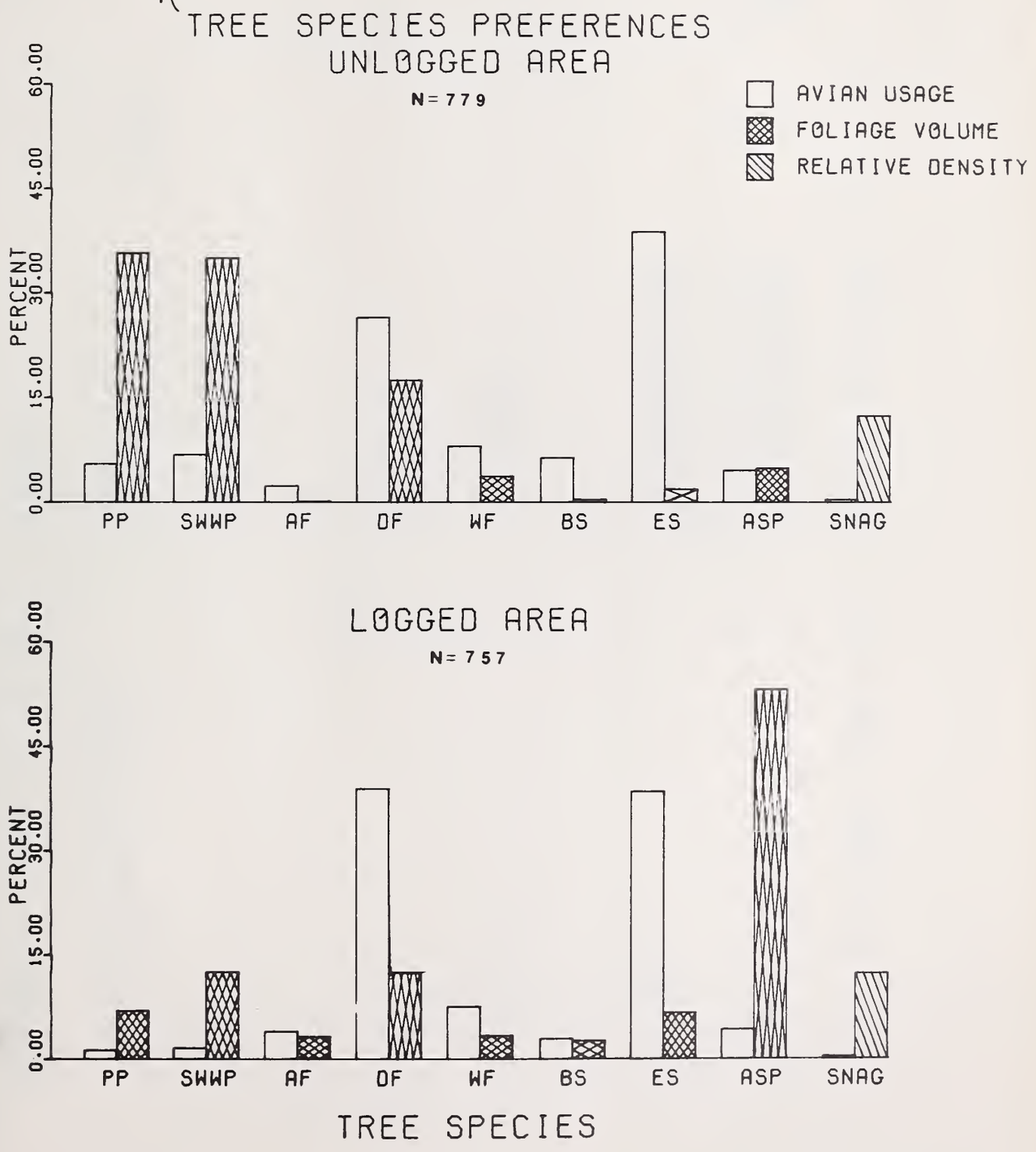
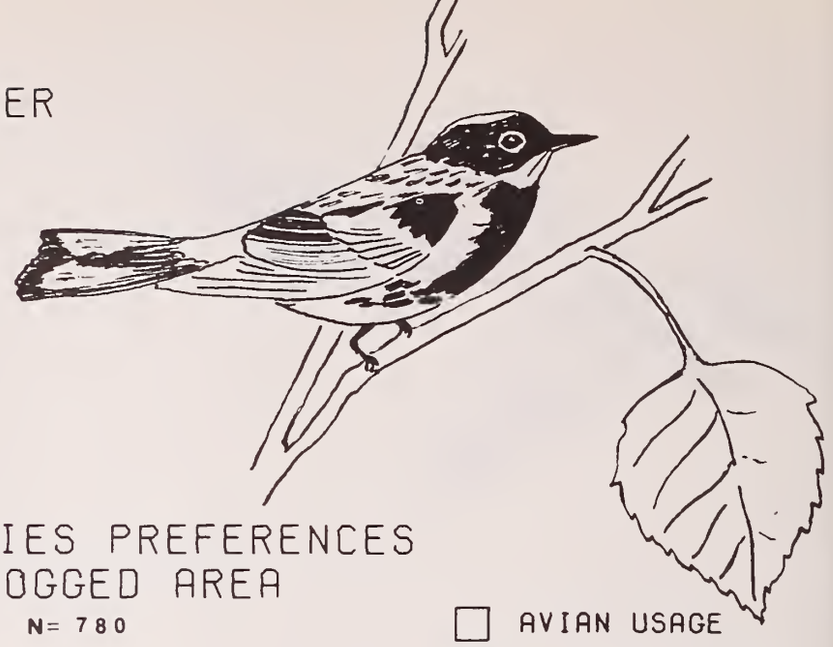


Figure 7.—Tree species preferences of the ruby-crowned kinglet.

YELLOW-RUMPED WARBLER



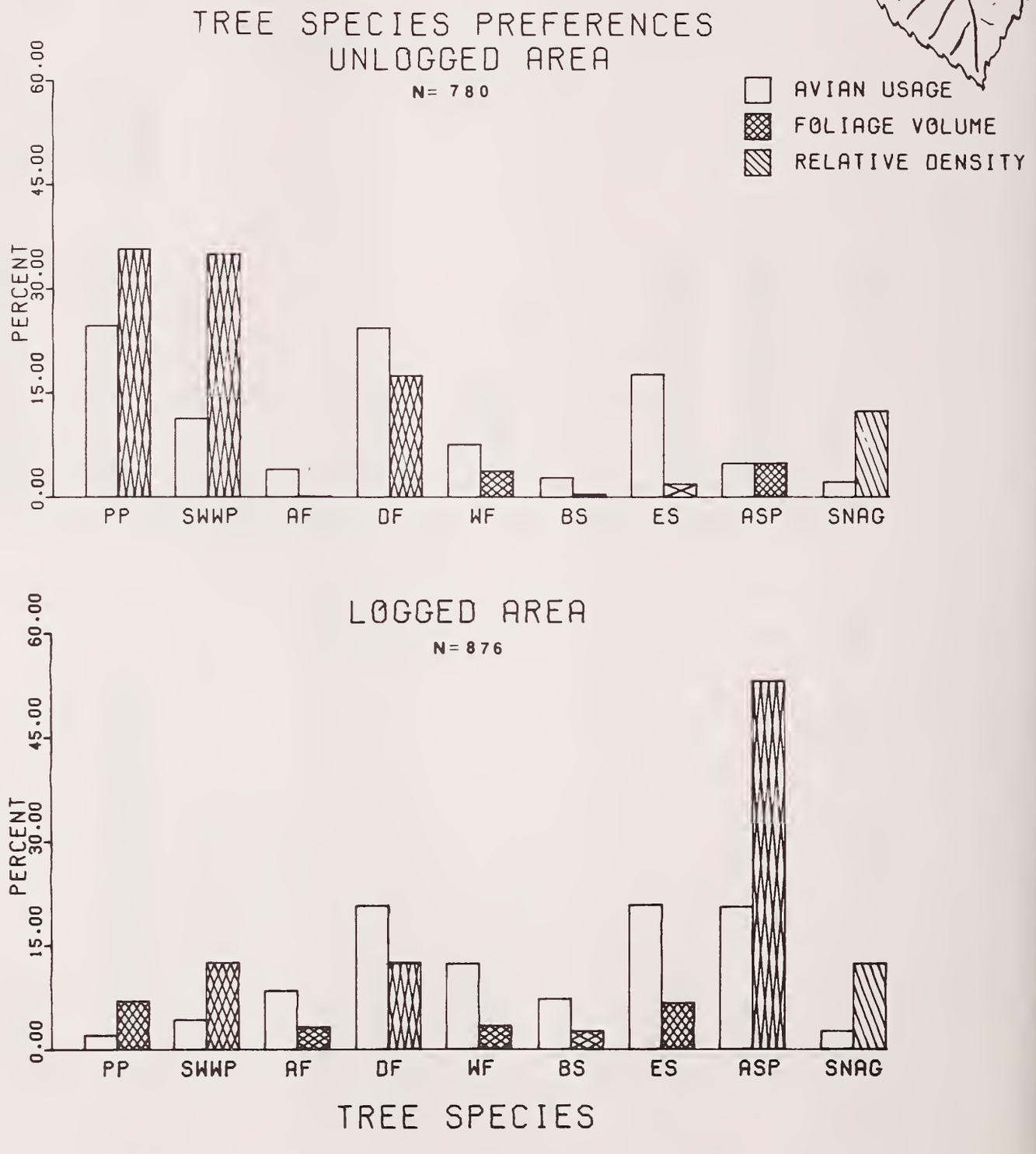
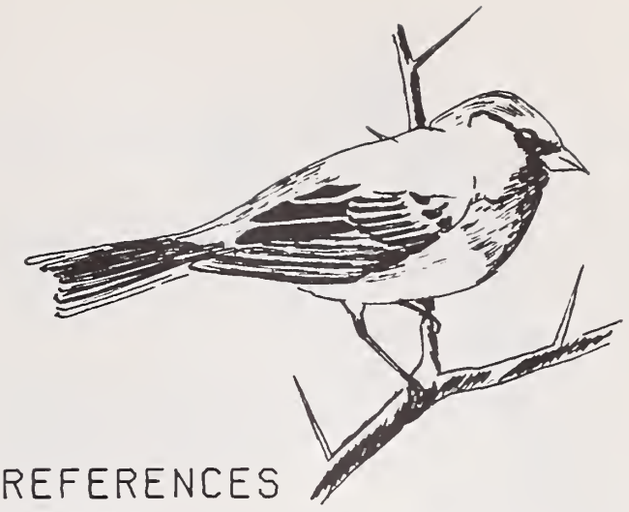


Figure 8.—Tree species preferences of the yellow-rumped warbler.

GRAY-HEADED JUNCO



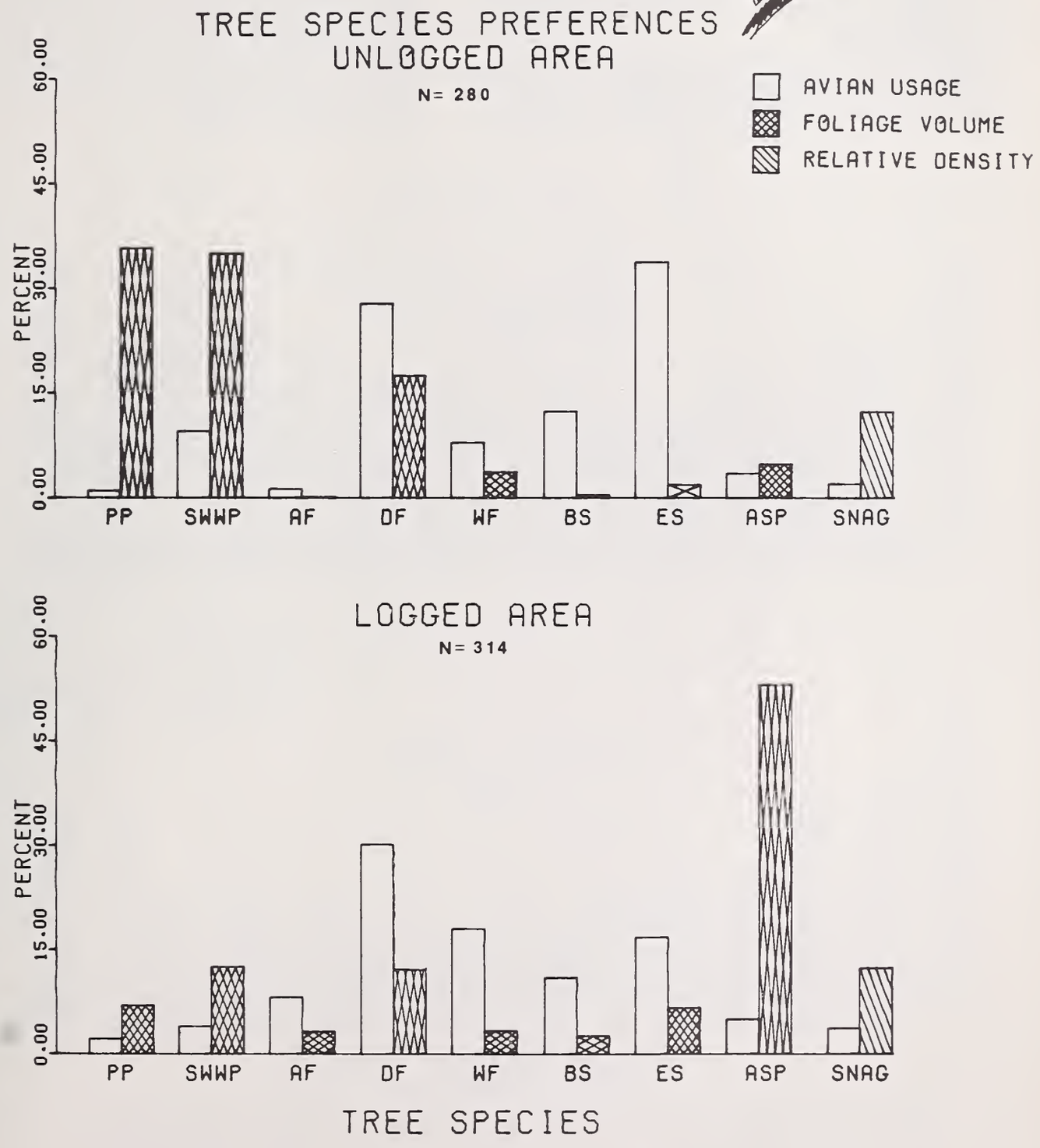


Figure 9.—Tree species preferences of the gray-headed junco.

Tree Height Preferences

Birds selected moderately tall and tall trees most frequently in both the control and harvested areas (fig. 10).

The yellow-bellied sapsucker mainly selected trees 21 m or taller in both logged and unlogged areas (fig. 11). Short trees were utilized infrequently. Height preferences were strikingly similar in both habitats.

The mountain chickadee showed a preference for trees taller than 18 m in both study areas (fig. 12). Smaller trees were utilized less frequently and tall trees more often in the control area than in the logged area.

In both the logged and unlogged areas, the ruby-crowned kinglet preferred trees 15 m or taller, and strongly preferred the tallest trees (fig. 13). This species used trees 24 m or taller considerably in excess of their frequency of availability.

The yellow-rumped warbler in both habitats also preferred the tallest trees (fig. 14). In the control area, trees less than 12 m were infrequently utilized. In the logged area, however, trees between 6 and 12 m were used far more often than in the control area.

Unlike the aforementioned species, the gray-headed junco substantially utilized the shorter trees (fig. 15). However, this species also showed a greater than expected use of the tallest trees. The majority of observations, however, were in relatively short trees (12 m or shorter).

Tree height preferences for all birds utilizing snags in the control area were not as well defined (fig. 16). In the logged area, a selection of snags 21 m or taller was evident.

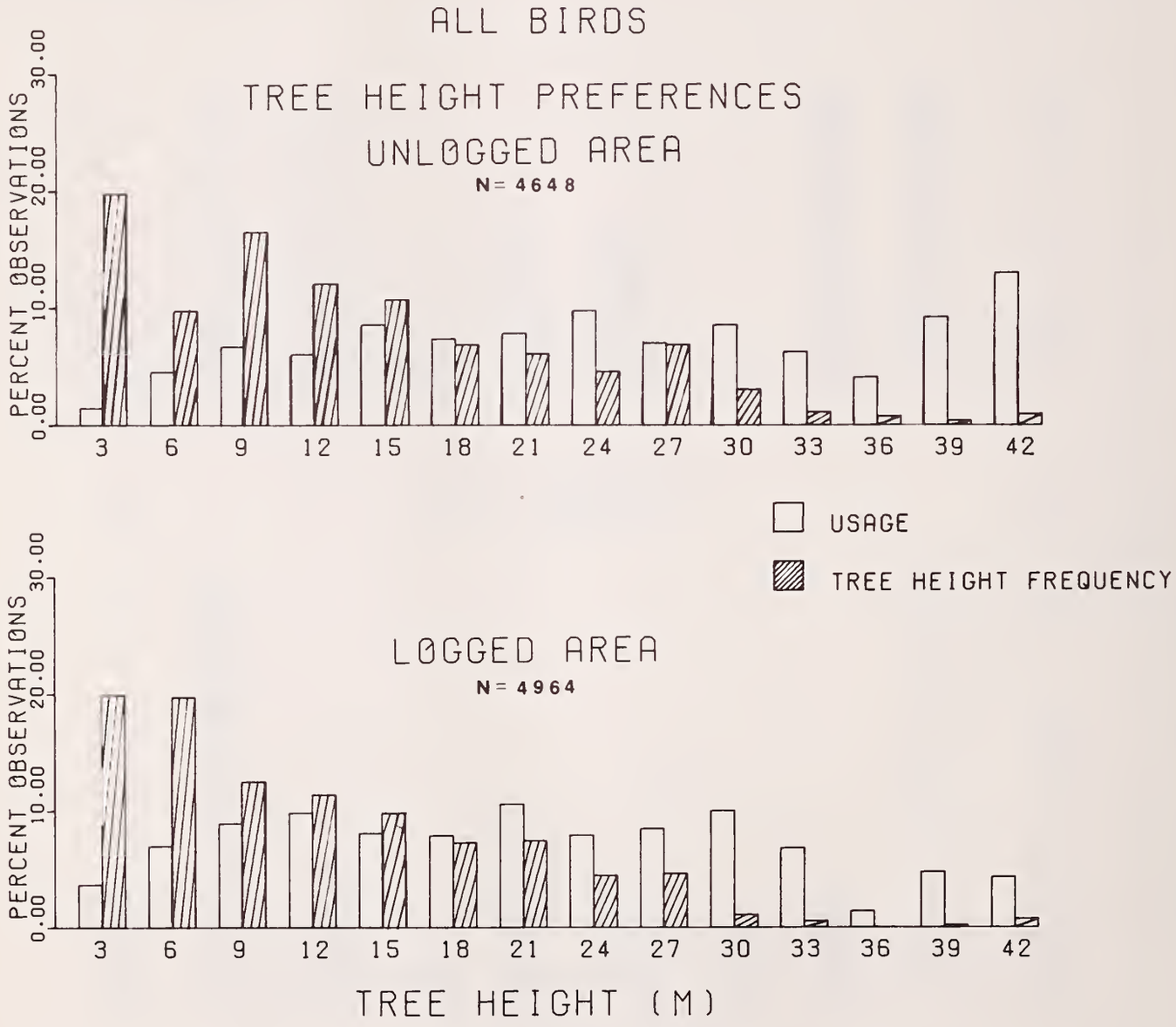


Figure 10.—Tree height preferences of all birds in the unlogged and logged areas.

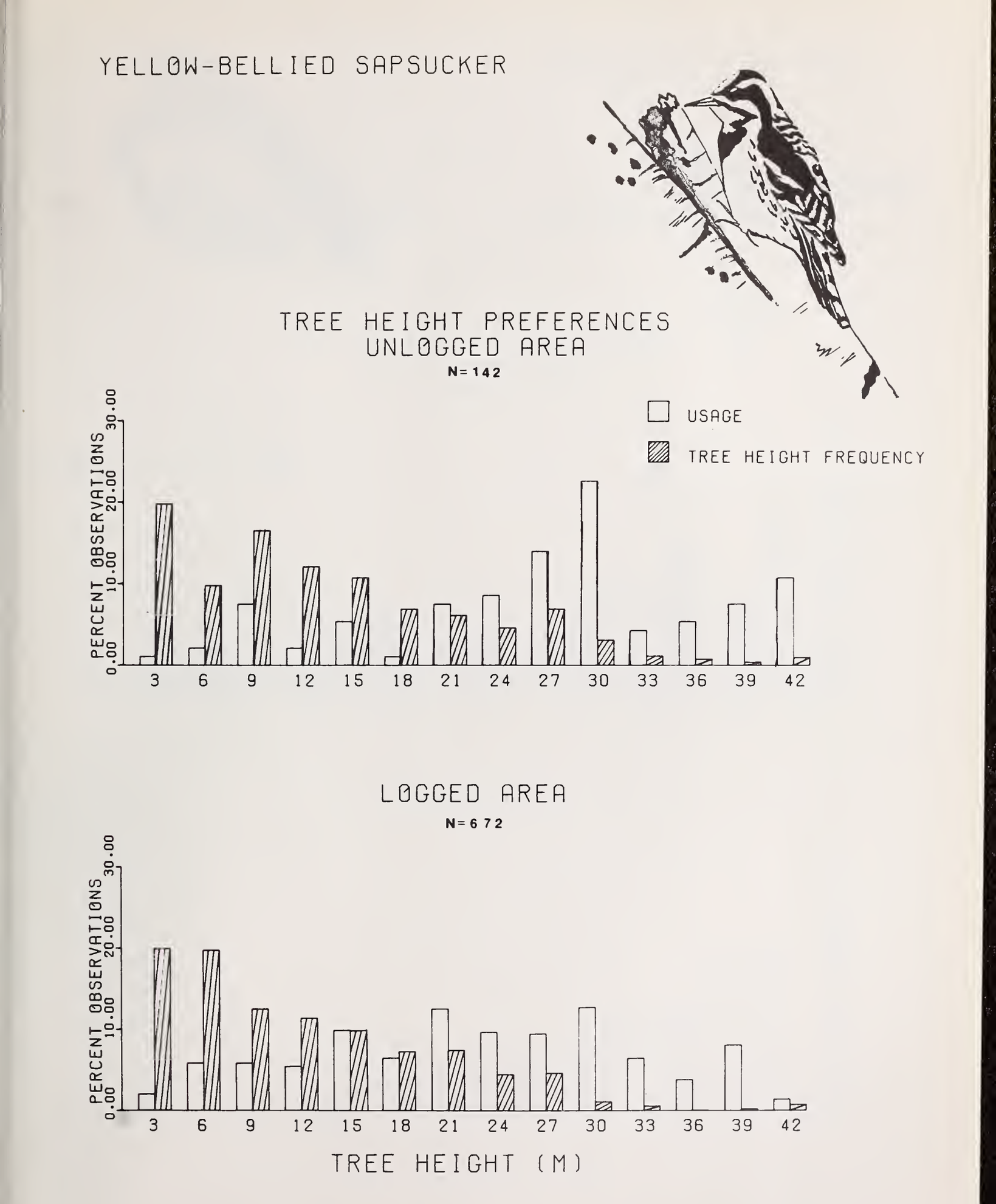


Figure 11.—Tree height preferences of the yellow-bellied sapsucker.

MOUNTAIN CHICKADEE

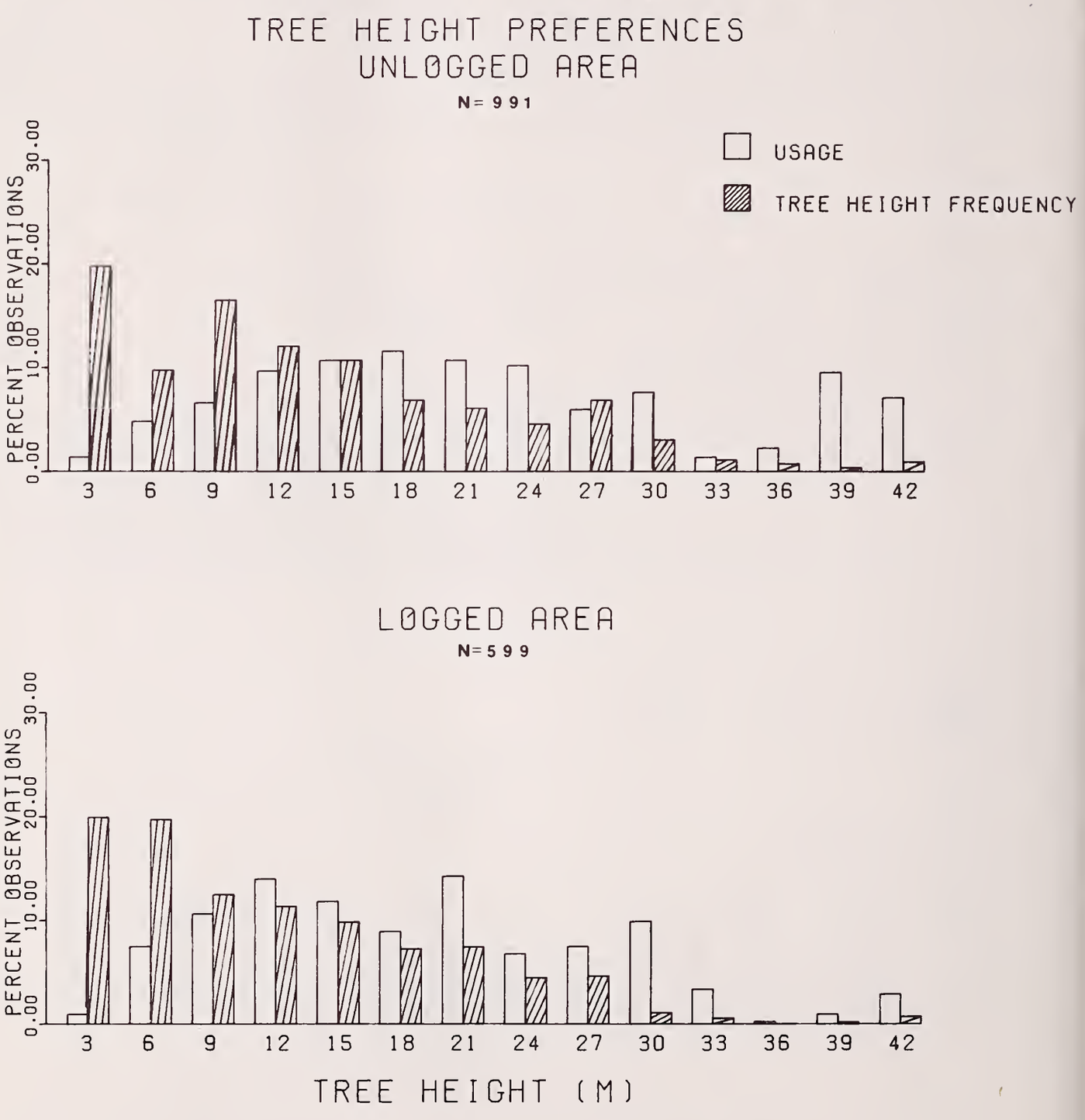


Figure 12.—Tree height preferences of the mountain chickadee.

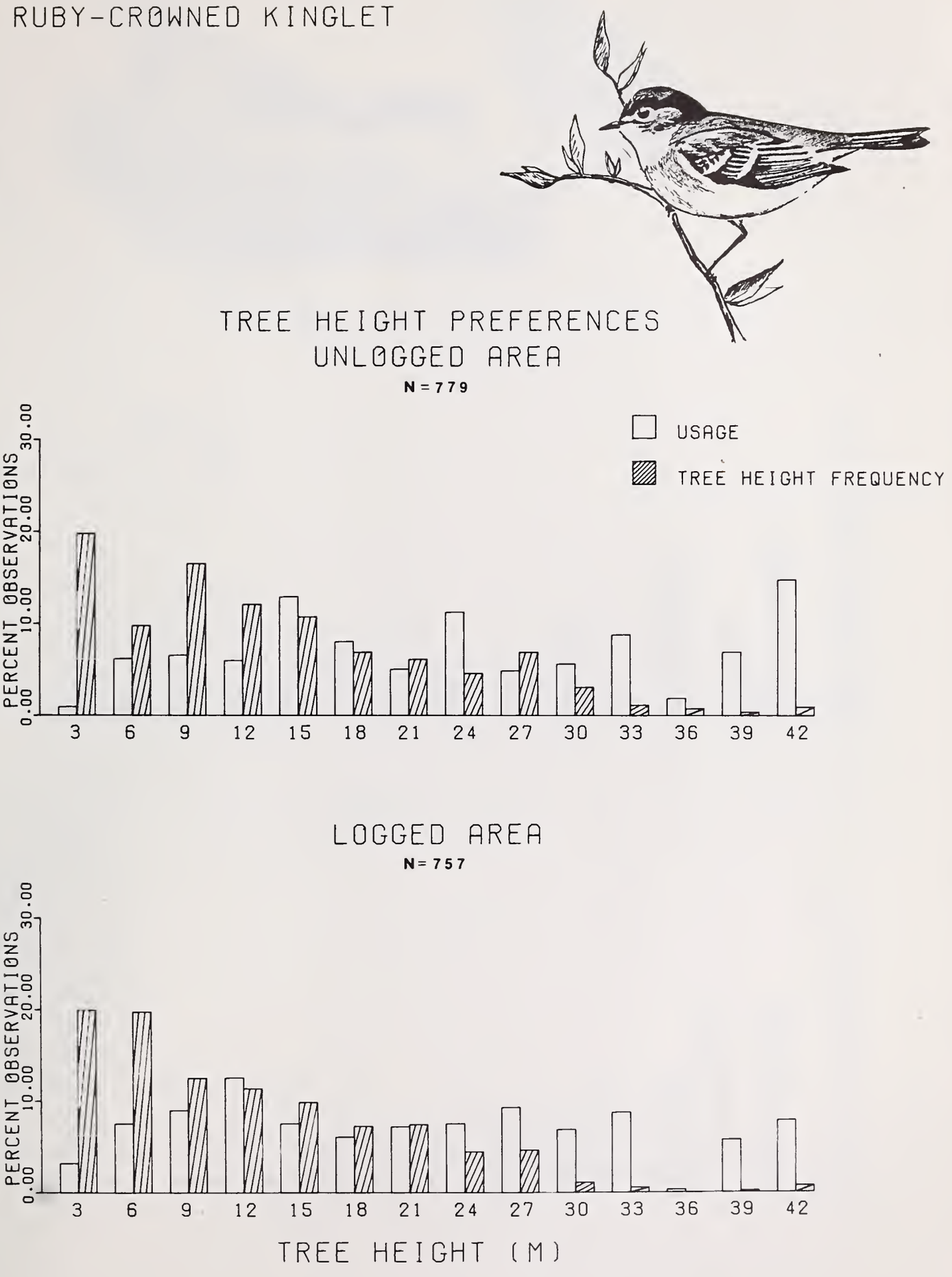


Figure 13.—Tree height preferences of the ruby-crowned kinglet.

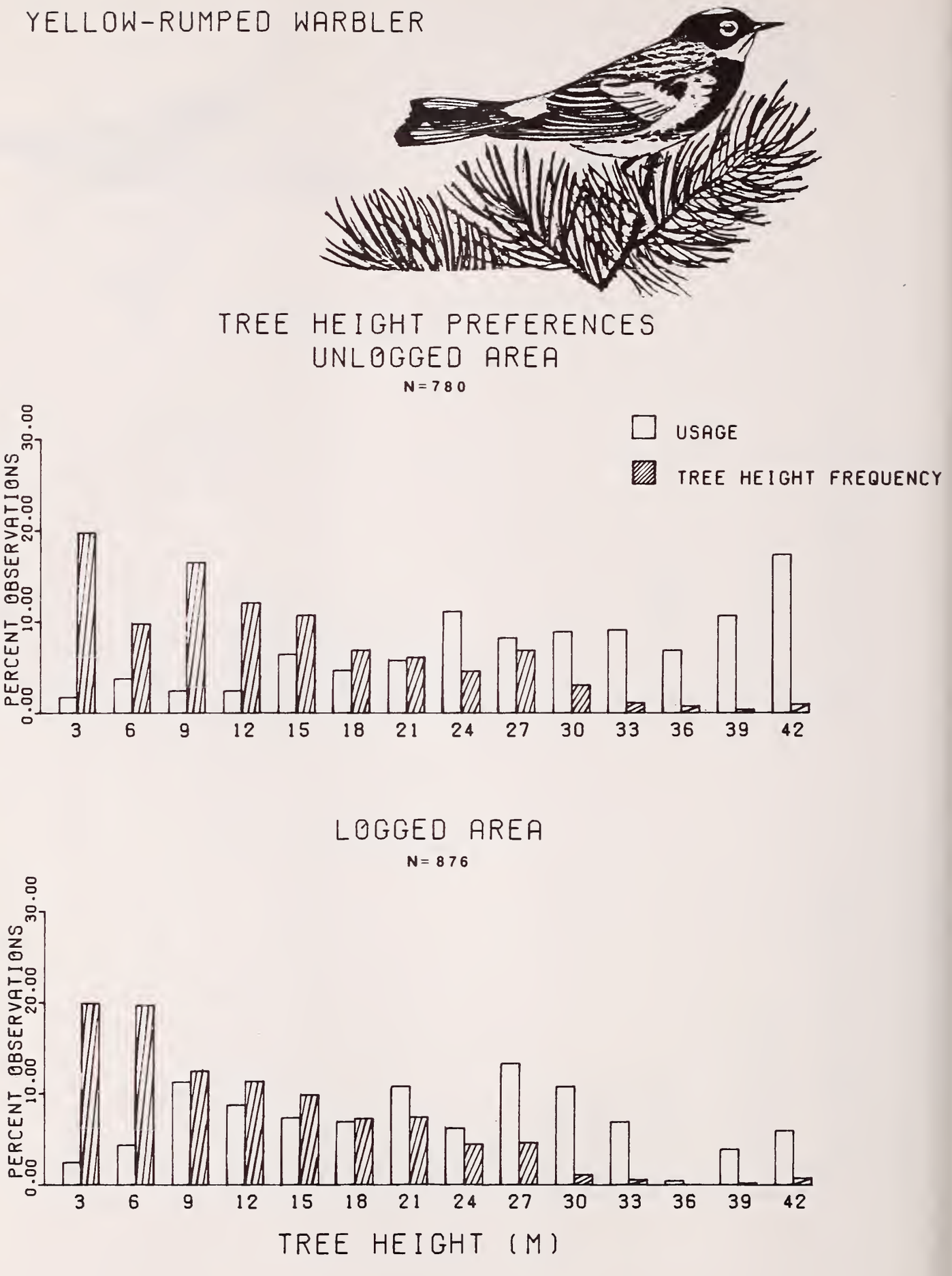


Figure 14.—Tree height preferences of the yellow-rumped warbler.

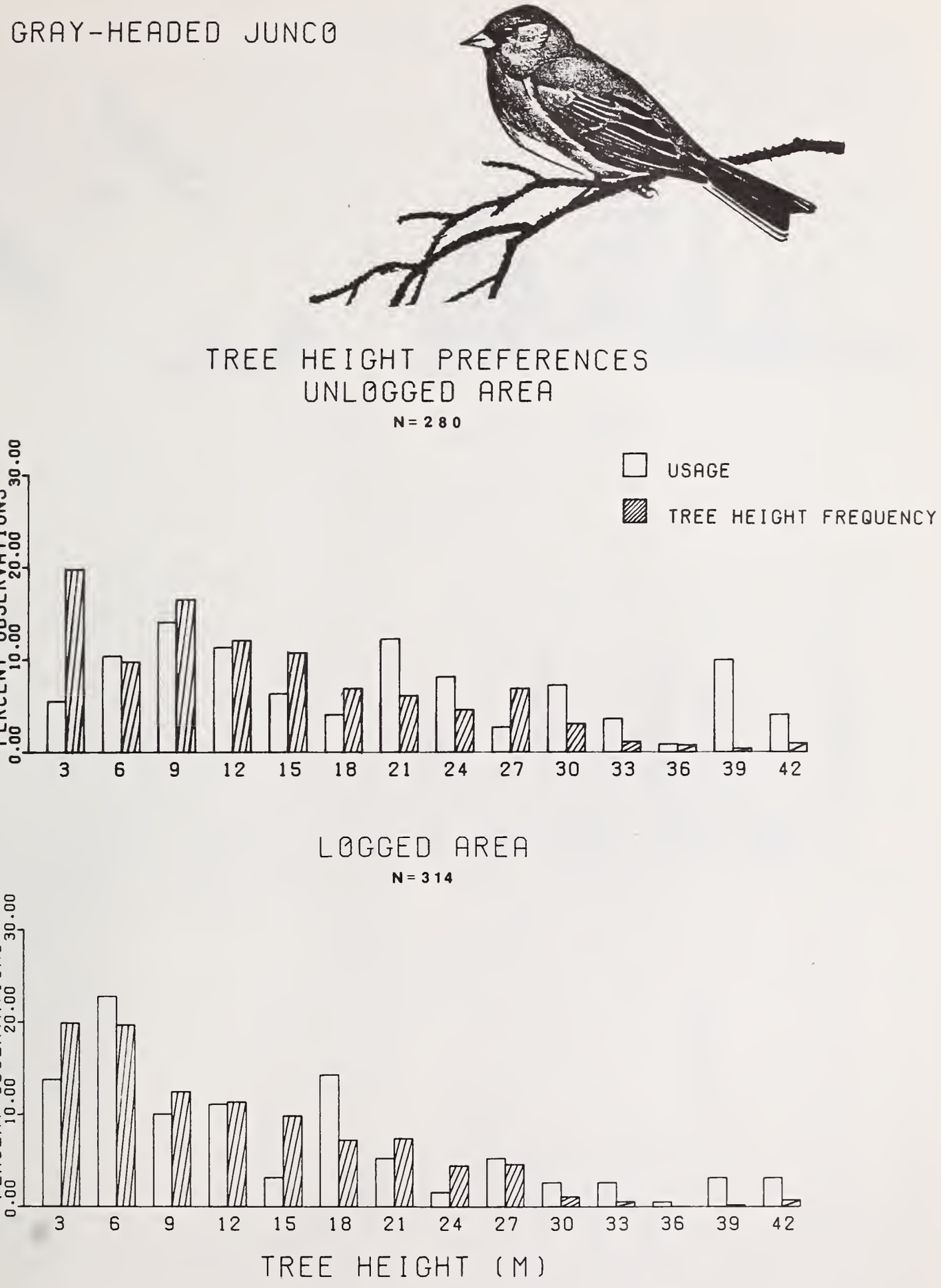


Figure 15.—Tree height preferences of the gray-headed junco.

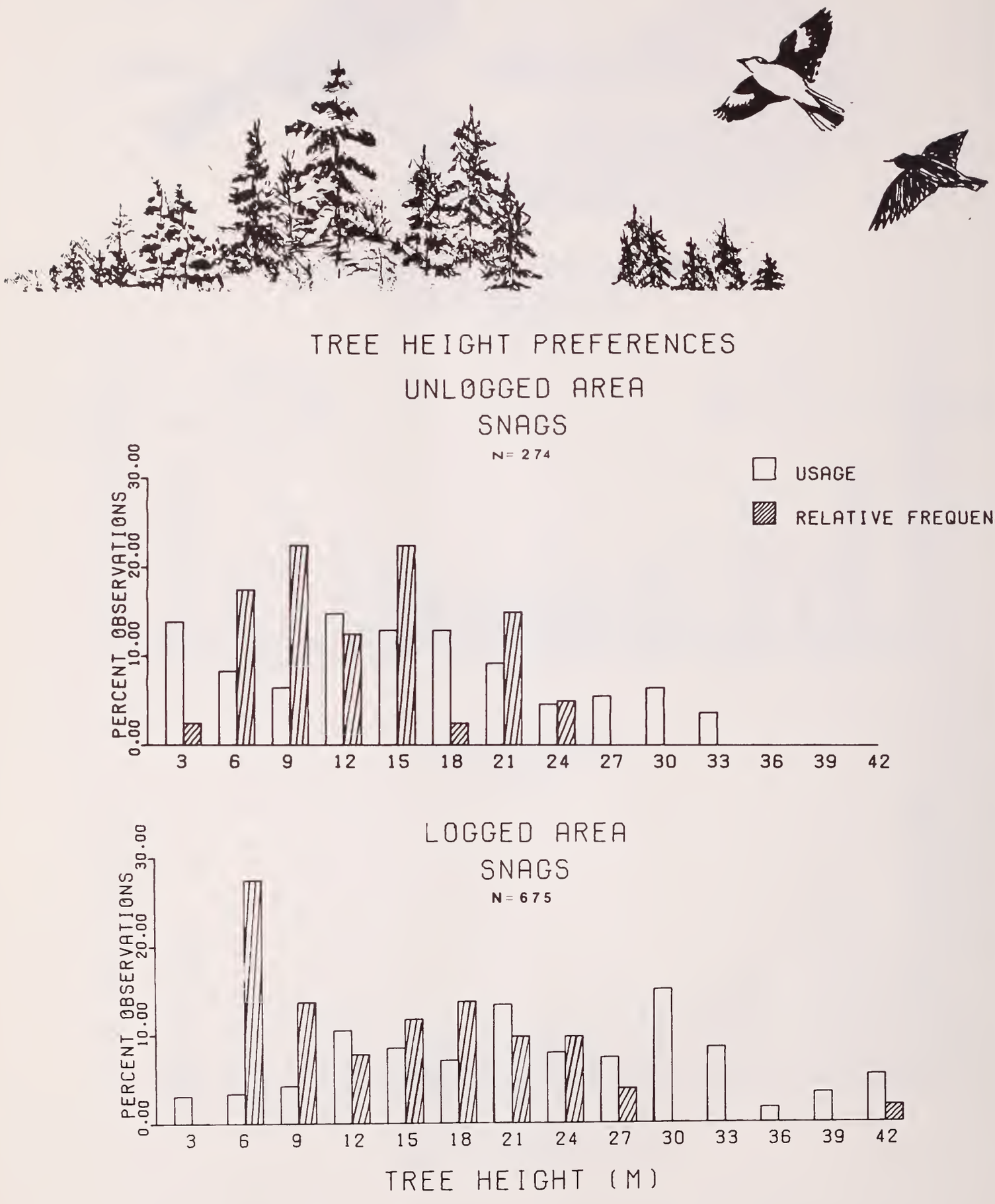


Figure 16.—Snag tree height preferences of all birds in the logged and unlogged areas.

Discussion

Avian Species Composition and Densities

Habitat parameters that may strongly influence species occurrence and densities include food availability and quality, climate, cover, nest sites, foliage volume, amount of open ground, tree density, and amount of canopy. Although the logged area of Willow Creek was only about 0.6 km from the control area, some of the above parameters undoubtedly differed between the two areas. However, microclimate, food, and amount of open ground were not measured.

The variation in species densities and distribution may reflect the climatic conditions of the preceding seasons. For example, a long, wet winter and spring in 1973 was considered responsible for keeping many birds from migrating to preferred high-mountain habitats (Monson 1973). A long, wet winter also may have affected numbers and species of insects of particular importance as food items. Climatic conditions, especially temperature, are critical in insect development and may account for 85 to 90 percent of insect mortality in the developmental stages (Bodenheimer 1928). Mean daily temperatures for Willow Creek during January and March of 1973 were lower than the corresponding period in 1974. Perhaps the cold spell reduced insect numbers, which in turn limited the number of birds the habitat could support.

Although tree species composition was the same for both study areas, there was a disparity in the amount of foliage and in the proportion that each tree species contributed to the community. The logged area provided birds with far less foliage in which to forage and nest than did the control area. Further, a large proportion of the foliage in the logged area consisted of aspen (53 percent), one of the least utilized tree species (Franzreb 1975).

Grace's warbler, found only in the control area in 1974, foraged primarily in large pines. Because very few pines of large or moderate size were left in the logged area, availability of this preferred tree species possibly restricted this warbler's distribution. Balda (1969) suggested that density of Grace's warbler may be determined by the available volume of foliage.

The brown creeper was almost totally restricted to the control area. Usually the creeper nested under the loosened bark of large ponderosa pine snags and foraged on trunks of medium to large trees. Its low density in the logged area may have been the result of reduced availability of either nesting sites or suitable trees on which to forage.

A number of foliage-gleaning species, such as the mountain chickadee, golden-crowned kinglet, ruby-crowned kinglet, yellow-rumped warbler, and red-faced warbler, were more common in the control area which afforded a larger volume of foliage. Such foliage may also contribute to protection against predators and inclement weather.

The western flycatcher — which forages by hawking — preferred denser vegetation and was considerably more numerous in the unmodified habitat. Davis et al. (1963) found that this species requires shade, while Carothers et al. (1973) noted its preference for dense aspen groves. The hermit thrush also selected areas with dense growth. Grinnell and Miller (1944) suggested that this thrush requires shade to escape from noonday heat.

Hagar (1960) found that clearcutting Douglas-fir resulted in a substantial change in avian species composition and a marked increase in total numbers within 3 yrs. Because Hagar sampled clearcut plots of 5.2 ha (13 acres), one might expect an increase in overall numbers and species due to edge effect. A number of species not found in Hagar's clearcut areas did occur in partially harvested Willow Creek. Presumably, the live trees remaining after overstory removal were sufficient for the western flycatcher, hermit thrush, and golden-crowned kinglet to breed, though in reduced numbers, whereas these species disappeared in Hagar's clearcut areas.

Snags were equally abundant in terms of relative density in both areas for cavity-nesting species. Birds sometimes competed for these cavities. For example, a pair of violet-green swallows unsuccessfully attempted to displace a pair of nesting mountain chickadees from their cavity in an aspen snag (Franzreb 1976).

The Williamson's sapsucker, hairy woodpecker, and northern three-toed woodpecker did not appear to differentiate between the control and logged habitats. Spruce beetle densities may increase in fallen trees and cull logs, which may enhance food availability for some woodpeckers (Baldwin 1968a, 1968b). Insects were not sampled in the study area, however.

Shook and Baldwin (1970) found more northern three-toed woodpeckers and hairy woodpeckers feeding on bark-beetle-infested Engelmann spruce logs in a selectively cut area than in either clearcut or uncut spruce forest. Hagar (1960) concluded that the common flicker and hairy woodpecker increased following logging, presumably because slash and isolated trees that may be dead or dying made the logged area more suitable than the unmodified habitat. Only the yellow-bellied sapsucker showed a consistent, significant increase in density in Willow Creek as the result of timber harvesting. An increase in either abundance of preferred food, accessibility of food, or total volume of food in

Willow Creek may have offset the effects of foliage reduction for woodpeckers. In addition, the increased accessibility to nest sites — usually constructed in aspen — may also partly explain why the yellow-bellied sapsucker found the logged area more suitable than the control site.

House wrens and gray-headed juncos, which forage primarily on the ground and debris, were particularly more prevalent in the logged area, especially in 1973 when an abundance of loose and piled slash provided foraging surface, observation posts, and — in the case of the junco — protection for nest sites. House wren and gray-headed junco densities changed little from 1973 to 1974, even though overall densities increased substantially in the logged area during this period. These two species might also have increased had the slash piles not been burned in late July 1973. In a study comparing clearcut areas to Douglas-fir forest in California (Hagar 1960), the dark-eyed junco, a congener of the gray-headed junco, was the most numerous of all birds in the cutover forest. Hagar concluded that "removal of logging debris constitutes a good control measure for juncos." Junco numbers following slash removal by burning in this study certainly support Hagar's findings.

Nest site preferences and foraging strategies are important determinants of species densities and occurrence in altered habitats (Bock and Lynch 1970). In the logged area in the present study, species such as the yellow-bellied sapsucker and hairy woodpecker nested in live trees and foraged in live and dead trees. Other species, including the mountain chickadee and brown creeper (unlogged area only), nested primarily in dead trees but foraged in live ones, while some both foraged and nested in live trees (ruby-crowned kinglet, yellow-rumped warbler). The gray-headed junco and house wren foraged and nested in the logged area, whereas other species visited the logged area to forage but nested primarily in the unmodified habitat. These included the northern three-toed woodpecker, red-faced warbler, and, infrequently, the brown creeper. Species that had higher densities in the control area were mainly bark searchers (pygmy nuthatch, brown creeper) and foliage gleaners (mountain chickadee, golden-crowned kinglet, yellow-rumped warbler).

Effects of Succession on the Bird Numbers and Diversity

Diversity values were higher in the control area than in the logged area for both summers. Information is lacking on avian succession in mixed conifer forests in the West. As trees increase in foliage volume, height, and diversity of life-form after harvesting, the number of niches available for birds also increases. Johnston and Odum (1956) found that each of the major successional stages had its distinctive breeding bird species and densities.

Numerous studies have indicated an increase in avian species through each stage in community succession, with the maximum occurring in the climax stage (Saunders 1936, Kendeigh 1948, Odum 1950, Johnston and Odum 1956, Haapanen 1965, Karr 1968, Shugart and James 1973). Kendeigh (1946) noted highest density in deciduous-coniferous ecotone stages instead of the climax stage. Karr (1968) found a decrease in bird species numbers in the last forest stage, a result in agreement with Margalef (1958).

The logged area of Willow Creek appeared similar in diversity to the control area, but it probably was incapable of supporting as large an avian population.

Tree Species Preferences

There are various possible explanations for avian selection of certain tree species, including food abundance, availability, and quality. The amount of foliage is also important since it provides sources of insect food, protection from predators and unfavorable weather, and shelters the nest site for many species. Adaptive characteristics must also be considered.

Southwood (1961) found that the number of insect species associated with given tree species varied in Britain. Among the genera of trees in his study — which occurred in Willow Creek — poplars (*Populus*), pines (*Pinus*), spruces (*Picea*), and firs (*Abies*), had 97, 91, 137, and 16 insect species, respectively. Southwood did not determine overall insect abundances, however. Insect abundance and number of species may also have varied among the tree species in Willow Creek.

The amount of foliage present may be related to insect numbers, as evidenced by the number of foraging observations in heavy foliage. However, in the unlogged study area in Willow Creek, such was probably not the case since ponderosa pine and southwestern white pine, the two tree species which contributed the greatest amount of foliage volume, were used far less than Douglas-fir and Engelmann spruce. In the harvested area, quaking aspen comprised almost 53 percent of the total available foliage but was utilized for less than 15 percent of the avian observations.

Foliage volume calculations, however, were based on formulas that did not consider that pine

and aspen foliage was much less dense than that of spruce and fir. The foliage per unit volume, therefore, was much higher for the latter tree species than for the pine and aspen. Hence the disparity between avian usage and calculated available foliage for some tree species may not be as great as the data suggest. These observations indicate that, even though amount of foliage may be a consideration in a bird's selection of a particular tree species, it is not the only variable.

Leaf morphology and size may influence the bird use of a tree species. The large leaves of quaking aspen make it difficult for most birds, particularly the smaller passerines, to perch on an aspen branch or twig and reach the middle and outer portions of the leaves which may harbor insects.

Tree Height Preferences

Previous studies assessing the height of a bird while utilizing trees have related such preferences to location of nest, song perches, and preferred foraging locations (Hartley 1953, MacArthur 1958, Kilham 1965, Ligon 1968, Morse 1968). Williamson (1971) found that the female red-eyed vireo foraged significantly more often at the height of her nest, whereas the male primarily confined his foraging activities to the area surrounding his singing perches.

Most prior studies have primarily examined the location of the bird in terms of distance from the ground. Few studies have considered the total height of trees used by the bird. Jackson (1970) found that heights of trees selected by foraging downy woodpeckers depended on sex of the bird and on whether the tree was alive or dead. In this study, most species preferred tall trees, and selected them more often than expected from relative frequency values. Perhaps this was the result of the proportionately large foliage volume in tall trees, thus permitting more extensive and prolonged foraging. A number of these species, such as the kinglets, nest relatively high in conifers. This may account for some of the observed higher utilization of tall trees if these birds were concentrating their activities near the nest or song post.

A comparison of tree height selection indicated strong preferences for tall trees by four of the five avian species considered. The yellow-bellied sapsucker, partly because it foraged primarily on the trunk, did not come in direct contact or conflict with the other four species, even though it commonly selected tall or moderately tall trees. The gray-headed junco also infrequently came in contact with the other three species because it preferred short trees in the unlogged habitat, and short or medium trees in the logged area. The mountain chickadee utilized medium-sized trees most, which minimized encounters with the yellow-rumped warbler and ruby-crowned kinglet. The latter two species have a greater potential for competition since they frequent tall trees. However, in the logged area, the yellow-rumped warbler preferred the moderately tall trees while the ruby-crowned kinglet used the tallest trees more.

In the unmodified habitat, however, the ruby-crowned kinglet used the short and medium-sized trees more, while the yellow-rumped warbler concentrated on the very tall and moderately tall trees. Variation in tree height selection may aid in resource allocation.

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Appendix I

Common and Scientific Names of Trees

Ponderosa pine	*Pinus ponderosa*
Southwestern white pine	*Pinus strobiformis*
Douglas-fir	*Pseudotsuga menziesii*
Subalpine fir	*Abies lasiocarpa*
White fir	*Abies concolor*
Blue spruce	*Picea pungens*
Engelmann spruce	*Picea engelmannii*
Quaking aspen	*Populus tremuloides*

Appendix II

Understory Vegetation

Shrubs	
Arizona rose	*Rosa arizonica*
Buckbrush	*Ceanothus fendleri*
Gooseberry	*Ribes montigenum*
New Mexican locust	*Robinia neomexicana*
Rabbit brush	*Chrysothamnus* spp.
Snakeweed	*Gutierrezia sarothrae*
Snowberry	*Symphoricarpos palmeri*
Grasses	
Arizona fescue	*Festuca arizonica*
Blue grama	*Bouteloua gracilis*
Canada bluegrass	*Poa compressa*
Deergrass	*Muhlenbergia rigens*
June grass	*Koeleria cristata*
Kentucky bluegrass	*Poa pratensis*
Mountain muhly	*Muhlenbergia montana*
Mutton bluegrass	*Poa fendleriana*
Nodding brome	*Bromus anomalus*
Roughbentgrass	*Agrostis scabra*
Pine dropseed	*Blepharoneuron tricholepis*
Sheep fescue	*Festuca ovina*
Slender wheatgrass	*Agropyron trachycaulum*
Smooth brome	*Bromus inermis*
Spike muhly	*Muhlenbergia wrightii*
Squirreltail	*Sitanion hystrix*
Timothy	*Phleum pratense*
Tufted hairgrass	*Deschampsia caespitosa*
Western wheatgrass	*Agropyron smithii*
Grass-like Plants	
Sedges	*Carex* spp.
Forbs	
Aster	*Aster* spp.
Bracken	*Pteridium aquilanum*
Cinquefoil	*Potentilla* spp.
Dandelion	*Taraxacum* spp.
Fleabane	*Erigeron* spp.
Gilia	*Gilia aggregata*
Goldenrod	*Solidago missouriensis*
Lupine	*Lupinus argenteus*
Peavine	*Lathyrus* spp.
Rocky Mountain iris	*Iris missouriensis*
Rough goldaster	*Chrysopsis lispida*
Russianthistle	*Salsola*
Sneezeweed	*Helenium hoopesii*
Strawberry	*Frageria bracteata*
Trailing fleabane	*Erigeron flagellaris*
Vetch	*Vicia americana*
Yarrow	*Achillea* spp.
Western yarrow	*Achillea lanulosa*

Appendix III

Common and Scientific Names of Birds

Turkey vulture	*Cathartes aura*
Goshawk	*Accipiter gentilis*
Red-tailed hawk	*Buteo jamaicensis*
American kestrel	*Falco sparverius*
Band-tailed pigeon	*Columba fasciata*
Mourning dove	*Zenaida macroura*
Flammulated owl	*Otus flammeolus*
Great horned owl	*Bubo virginianus*
Pygmy owl	*Glaucidium gnoma*
Saw-whet owl	*Aegolius acadicus*
Broad-tailed hummingbird	*Selasphorus platycercus*
Rufous hummingbird	*Selasphorus rufus*
Common flicker	*Colaptes auratus*
Yellow-bellied sapsucker	*Sphyrapicus varius*
Williamson's sapsucker	*Sphyrapicus thyroideus*
Hairy woodpecker	*Dendrocopos villosus*
Downy woodpecker	*Dendrocopos pubescens*
Northern three-toed woodpecker	*Picoides tridactylus*
Dusky flycatcher	*Empidonax oberholseri*
Western flycatcher	*Empidonax difficilis*
Coues' flycatcher	*Contopus pertinax*
Olive-sided flycatcher	*Nuttallornis borealis*
Violet-green swallow	*Tachycineta thalassina*
Purple martin	*Progne subis*
Steller's jay	*Cyanocitta stelleri*
Common raven	*Corvus corax*
Clark's nutcracker	*Nucifraga columbiana*
Mountain chickadee	*Parus gambeli*
White-breasted nuthatch	*Sitta carolinensis*
Red-breasted nuthatch	*Sitta canadensis*
Pygmy nuthatch	*Sitta pygmaea*
Brown creeper	*Certhia familiaris*
House wren	*Troglodytes aedon*
American robin	*Turdus migratorius*
Hermit thrush	*Catharus guttatus*
Western bluebird	*Sialia mexicana*
Mountain bluebird	*Sialia currucoides*
Townsend's solitaire	*Myadestes townsendi*
Golden-crowned kinglet	*Regulus satrapa*
Ruby-crowned kinglet	*Regulus calendula*
Solitary vireo	*Vireo solitarius*
Red-eyed vireo	*Vireo olivaceus*
Warbling vireo	*Vireo gilvus*
Orange-crowned warbler	*Vermivora celata*
Virginia's warbler	*Vermivora virginiae*
Olive warbler	*Peucedramus taeniatus*
Yellow-rumped warbler	*Dendroica coronata*
Grace's warbler	*Dendroica graciae*
Yellow warbler	*Dendroica petechia*
Red-faced warbler	*Cardellina rubrifrons*
Western tanager	*Piranga ludoviciana*
Black-headed grosbeak	*Pheucticus melanocephalus*
Cassin's finch	*Carpodacus cassinii*
Pine siskin	*Spinus pinus*
Red crossbill	*Loxia curvirostra*
Green-tailed towhee	*Chlorura chlorura*
Savannah sparrow	*Passerculus sandwichensis*
Dark-eyed junco	*Junco hyemalis*
Gray-headed junco	*Junco caniceps*
Chipping sparrow	*Spizella passerina*
White-crowned sparrow	*Zonotrichia leucophrys*

Franzreb, Kathleen E.
1977. Bird population changes after timber harvesting of a mixed conifer forest in Arizona. USDA For. Serv. Res. Pap. RM-184, 26 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

Selective overstory removal in a mixed conifer forest in the White Mountains of Arizona significantly reduced total bird density. However, a number of species attained higher densities in the logged area than in the control area. In both habitats, avian usage of Douglas-fir, white fir, and Engelmann spruce far exceeded that expected on the basis of foliage volume. Birds were more frequently observed on snags and in quaking aspen in the logged area than in the control site. Gray-headed juncos utilized logging slash heavily. Tall trees were preferred in both habitats.

Keywords: Timber harvesting, mixed conifer forest, bird population changes.

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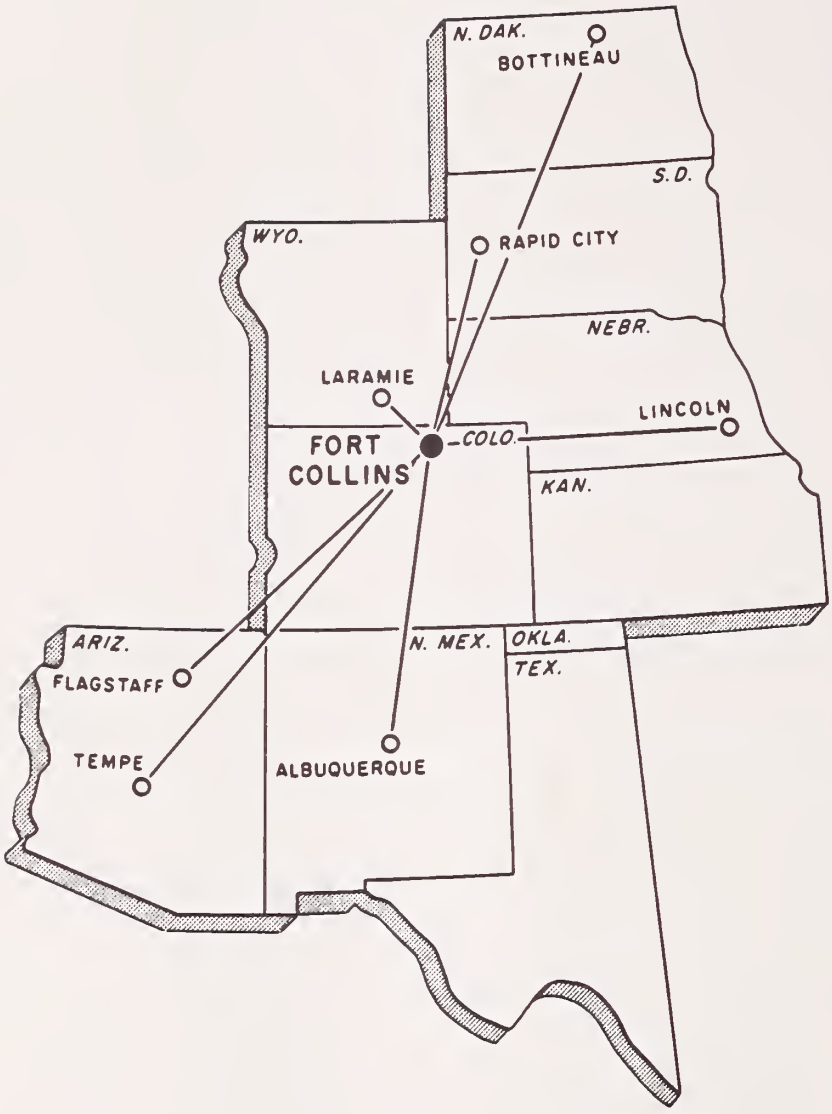
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